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Method for the production of structural components from fibre-reinforced thermoplastic material

The invention is related to a method for the production of structural components from long fibre thermoplastic with integrated continuous fibre reinforcements according to the generic term of claim 1 as well as to an installation for the production of structural components of this kind. Known methods for the production of such structural components in most cases utilise plane continuous fibre reinforcements, e.g., in the form of semi-finished fabric products or with a sandwich structure, which, however, are very limited with respect to possible shaping and applications.

From WO99/52703 a method for the production of structural components is known, in the case of which molten continuous fibre strands are deposited on top of one another, so that they form a coherent load-bearing structure with plane joints and are pressed in a tool together with a forming mass reinforced with long fibres. Also these known processes, however, still manifest essential disadvantages with respect to efficient production, reproducibility and a defined development of an integrated continuous fibre load-bearing structure. In this manner it is not possible to produce a defined, single piece structural component, which can be made in a single press step and which comprises an integrated, precisely defined, optimally positioned and shaped, load-optimised continuous fibre reinforcing structure.

It is therefore the purpose of the invention presented here to overcome the disadvantages and limitations of the known production methods and to create a method for the efficient automatic production of structural components, which overcomes the disadvantages and limitations applicable up until now and to produce single piece components capable of being pressed in a single step and with an integrated, precisely defined, optimally positioned and three-dimensionally shaped reinforcing structure, which corresponds to the loads and forces to be absorbed. This objective is achieved according to the invention by a method for the production of structural components

according to claim 1 and by an installation for the production of structural components according to claim 29. By means of the defined, short shock-cooling with EF(continuous fibre) - profile shaping and the formation of a dimensionally stable casing layer a precisely defined shape and positioning of EF - profiles in the LFT (long fibre thermoplastic) - mass as well as an optimum bonding at the interface is achieved.

The dependent claims are related to advantageous further developments of the invention with particular advantages with respect to efficient cost-effective series production capable of being automated, with short cycle times as well as optimum alignment and forming of the continuous fibre reinforcing structures with improved mechanical characteristics. With this, it is possible to produce light structural components for a large number of applications, e.g., for means of transportation, vehicles and vehicle components with load-bearing functions and this in a simple and precise manner.

In the following the invention is further explained on the basis of examples of embodiments and Figures, which illustrate:

Fig. 1	schematically the method according to the invention with profile shaping and defined shock-cooling,
Fig. 2	temperature dependence in an EF - profile during the shock-cooling for different shock-cooling periods,
Fig. 3	temperature dependence in an EF- profile during the shock-cooling for different tool temperatures and heat transfers,
Fig. 4	an example with the shock-cooling differing zone by zone on an EF - profile,
Fig. 5a	the enthalpy in function of the temperature during the heating-up and cooling-down of partially crystalline thermoplastics with a crystallisation hysteresis range,
Fig. 5b	the temperature control on the surface during the shock-cooling in the enthalpy diagram,
Fig. 5c	the temperature control in the lower layer during the shock-cooling in the enthalpy diagram,

Fig. 6	the temperature distribution in the EF – profile following the shock-cooling,
Fig. 7	the temperature distribution in the EF - profile and in the LFT - layer during the pressing in the LFT - tool,
Fig. 8a	an arrangement of several EF - profiles in a structural component with a three-dimensional intersection point,
Fig. 8b	the LFT - shaping of the structural component with integrated EF - profiles,
Fig. 8c	a two-stage profile forming process,
Fig. 9a, b	two different cross section shapes of an EF - profile at different places in a rib,
Fig. 10	an inverse tempered EF - profile,
Fig. 11	an EF - profile production line with an EF - profile - forming station,
Fig. 12	an installation for the production of the structural components according to the invention with EF - profile forming station and LFT -press,
Fig. 13	a positioning of EF - profiles on top and at the bottom in an LFT - pressing tool,
Fig. 14	a structural component as a bumper beam support,
Fig. 15	a structural component as an assembly support (front end).

Fig. 1 schematically illustrates the method according to the invention for the production of structural components out of long-fibre thermoplastic material (LFT) with integrated continuous fibre (EF) - reinforcements in a single stage LFT - pressing process by means of shock-cooling and EF - profile compression moulding in its sequence. In a heating station 15 impregnated, resp., pre-consolidated EF – tapes or bands 5 are completely melted to a practically homogeneous temperature Tp0, which is situated clearly above the melting point Tm, and subsequently transferred into a two-part profile tool 21 (here in 21u) of an EF - profile forming station 20. Here the EF - tapes 5 with an input temperature Tp are formed into the required EF - profile 10 by means of a short time pressing during a precisely defined shock-cooling period ts. During this form pressing and shock-cooling, through the contact with the thermally conditioned profile tool 21,

resp., 21o (upper) and 21u (lower), with a defined, relatively low tool temperature Twp and through a high heat transfer Q1 from the hot EF - profile into the profile tool 21 a shock-cooled, dimensionally stable thin casing layer 12 is formed. After a defined shock-cooling - and pressing period ts, the EF - profile 10 is immediately completely separated from the profile tool, transferred into an LFT - tool 31 (31o, 31u) of an LFT - press 30 and there positioned in a precisely defined manner in suitable shapings of the tool. Subsequently a molten LFT - mass 6 with a temperature Tf, which is situated above the melting point Tm, is introduced and put under pressure together with the EF - profile 10 and pressed, so that the casing layer 12 at the surface 11 of the EF - profiles is melted open again and is thermoplastically melted together with the introduced surrounding LFT - mass 6.

These structural components comprise at least one integrated, shock-cooled EF - profile. The temperature control during this process, i.e., the adjustment of the thermal and temporal parameters and of the shock-cooling period ts takes place in correspondence with the following requirements, which are capable of being achieved with the method according to the invention:

a At the contact points of the EF - profile with a gripper for the transfer into the LFT - press 30, a non-sticking, solid profile surface is formed.

b The dimensional stability of the EF - profiles 10 during the transfer into the LFT - press has to be sufficient, so that the EF - profiles are capable of being positioned in the LFT - tool precisely in the required position and shape.

c The shape preservation of the EF - profile during the pressing with the LFT - mass 6 in the LFT - press is adjusted in such a manner, that following the pressing the required final shape of the EF - profile results in the component depending on the local requirement (from a required complete shape preservation up to in zones strong merging of the EF - profile into the surrounding LFT - mass).

d The interface joint at the contact surfaces 9 between the EF - profile and the surrounding LFT - mass has to achieve the required strength.

Correspondingly the development of the solidified casing layer 12 is selected to be larger or smaller.
Applicable as a rough guideline is: the stronger the shock-cooling, the greater the preservation of the shape (characteristics a, b, c)
and with a lesser shock-cooling the shape change during the pressing is enhanced and at the beginning also the interface bonding (characteristic d) is strengthened.

An example with a high degree of shape preservation is shown in Fig. 9a with an EF - profile in a rib. On one side of the EF - profile (adjacent to the lower LFT - tool 31u) a stronger shock-cooling with a stronger casing layer is able to take place, while on the opposite side of the EF - profile nonetheless a good interface bonding with the introduced surrounding LFT - mass 6 is achieved by means of a medium shock-cooling with a normally formed casing layer (on the side of the upper LFT - tool 31o of Fig. 1).

In general a surface 11 of the EF - profiles adjacent to the LFT - tool 31 is able to be previously strongly shock-cooled on one side (because it afterwards after all does not have to be bonded to LFT - mass) and simultaneously the opposite side is able to be shock-cooled less strongly for the optimum bonding with the LFT - mass (refer to Fig. 4).

The optimum temperature control corresponding to the respective requirements of the EF - profiles (10) is achieved by a corresponding adjustment of the process parameters. These are:

Tp the input temperature of the EF - profile prior to the shock-cooling, after the heating up to a homogeneous temperature Tp0 in the heating station 15.

During the shock-cooling:

ts the shock-cooling period, i.e., the duration of the pressing and with this of the heat transfer Q1

Twp the temperature of the profile tool 21

ae the heat penetration coefficient during the contact with the tool 21; this is determined by the choice of material and the characteristics of the tool: specific heat c, thermal conductivity λ and specific density ρ.
This results in $ae = (\lambda . \rho . c)^{1/2}$.

Q1 the heat transfer from the EF - profile 10 to the tool 21 is therefore given by Q1 = f(ts, Tp - Twp, ae).

Ta, Ti temperatures on the surface 11 of, resp., inside the EF - profile

tt transfer time up to the contact of the EF - profile with the LFT - mass in the LFT - press.

Heat transfer during the LFT - pressing:

Tf temperature of the introduced LFT - mass 6 prior to the pressing

Twl temperature of the LFT - tool 31

Q2 the heat transfer from the hot LFT - mass 6 to the EF - profile 10 here results as a function f(Q1, Ta, Ti, Tf, Twl).

During the adjustment of these parameters, also the thickness dp of the EF - profiles and the materials characteristics are included. The thickness dp, for example, may be between 2 and 5 mm.

The following Figs. 2, 3 schematically illustrate different settings of the shock-cooling parameters. They illustrate temperature dependences in an EF - profile T(d) over the layer thickness dp after a shock-cooling carried out at the time t = ts.

Fig. 2 illustrates two temperature dependences T1(d), T2(d) for two different shock-cooling periods ts1, ts2, with the same tool temperature Twp. The longer shock-cooling period ts1 with a heat transfer Q1.1 results in a correspondingly stronger, thicker casing layer 12.1 (solidified below the melting temperature Tm) and the shorter shock-cooling period ts2 with a lesser heat transfer Q1.2 results in a thinner casing layer 12.2.

Fig. 3 illustrates different temperature dependences T(d) with a constant shock-cooling period ts, however, with different tool temperatures Twp1, Twp2, Twp3 with corresponding heat transfers Q and the resulting casing layers 12, wherein the intensity of the shock-cooling decreases from T1 to T4 (refer to Fig. 4):

T1: Twp1 =	strong shock-cooling Q1.1 and casing layer 12.1
T2: Twp2 =	medium shock-cooling Q1.2 and casing layer 12.2
T3: Twp3 =	weak shock-cooling Q1.3 and casing layer 12.3
T4:	no contact with the tool (open points, recesses, Fig. 4), Q1.4 = 0, i.e., no thermal transfer.

In this, the surface temperatures Ta of the EF - profile correspond to the tool temperatures Twp and the temperatures inside the profile Ti are situated in the vicinity of the input temperature Tp of the heated EF - tape. In preference short shock-cooling periods ts and low tool temperatures Twp are selected.
The shock-cooling periods ts in preference amount to between 1 and 5 sec., frequently approx. 2 – 4 sec., wherein in special cases also longer times, e.g., of up to 10 sec. would be possible. The transfer times tt in the LFT - press amount to, e.g., between 5 and 20 sec.

By means of the adjustment of the parameters and with it of the temperature control, the shock-cooling is correspondingly adjusted to the respective requirements in order to:

- achieve the optimum dimensional stability for the handling of the EF - profiles and for the required final shape of the profile after the pressing operation and
- achieve an optimum bonding between the EF - profile and the LFT - mass (bond strength).

Differing requirements in certain zones, however, may be demanded of an EF - profile (with respect to the criteria a, b, c, d mentioned above), this in correspondence with the function of the respective part or of the side or of the zone of an EF - profile. For

example, of an EF - profile of Fig. 9a or in the case of a component of Fig. 8, above all also in zones of force transfers and force introductions.

It is a very important advantage of the shock-cooling and profile shaping according to the invention, that the shock-cooling on the EP - profiles is capable of being adjusted differently and respectively to an optimum zone by zone. This is explained in conjunction with Fig. 4. It schematically illustrates different zones with differing shock-cooling in longitudinal direction on an EF - profile 10, e.g., with reducing intensity of the shock-cooling from Q1.1 to Q1.4 in analogy to the example of Fig. 3. In doing so, these differing zones on the profile tool 21 may comprise differing temperatures Twp1, Twp2, Twp3 as well as also differing material characteristics ae1, ae2, ae3. As illustrated in Fig. 4, both sides of the EP - profile on top and underneath are also capable of being differently shock-cooled with the corresponding profile tool parts 21o und 21u. The differing zones on the tool 21 are capable of being achieved by thermal conditioning (heating, cooling) and the tool temperature Twp as well as by the material characteristics ae, i.e., metallic materials and possibly local insulating coatings.

The following materials are suitable for the method according to the invention: The LFT - mass 6 in preference comprises an average fibre length of at least 3 mm, even better mechanical properties are achieved with greater fibre lengths of, e.g., 5 – 15 mm. The continuous fibre reinforcement (EF) may consist of glass -, carbon - or aramide fibres (wherein in special cases also boron fibres for the highest compressive strength or steel fibres would not be excluded).

The EF - profiles may, e.g., mainly be built-up of UD (unidirectional) - layers (0°) or continuous fibre strands of different kinds, also, however, of layers with differing fibre orientations, e.g., alternately with layers of 0°/90° or 0°/+45°/-45° fibre orientations. They may also comprise a thin surface layer (e.g., 0.1 – 0.2 mm) made of pure thermoplastic material without any EF - fibre reinforcement.

The shock-cooling method according to the invention is particularly suitable for crystalline materials by means of the exploitation of the crystallisation characteristics. Especially suitable for structural components are crystalline, resp., partially crystalline polymers as matrix of EF - profiles 10 and of LF - mass 6, this also because these are capable of achieving higher compressive strengths. It is also possible, however, to utilise amorphous polymers such as ABS or PC. The crystalline thermoplastic material may consist, e.g., of polypropylene (PP), polyethylene-therephtalate (PET), polybutylene-therephtalate (PBT) or polyamide (PA) and others. In the following, the crystalline behaviour and the shock-cooling is further explained on the basis of polypropylene PP and its application in the method according to the invention.

For this purpose in Fig. 5a an enthalpy diagram of PP is depicted as an example, i.e., the enthalpy in function of the temperature En(T). During melting or heating-up according to curve a, the enthalpy increases strongly ahead of the melting point Tm of approx. 165° C, this as a result of the melting of the crystalline zones. During the subsequent slow cooling-down according to curve b, the polymer remains amorphously molten up to a lower solidification temperature Tu of approx. 125° C and the enthalpy only strongly declines below Tu in the temperature range of the crystal growth DTkr of approx. 70 – 125°C (the crystal growth in the range of DTkr is shown by the curve kr). In between there is the hysteresis range DEn, which corresponds to the latent heat of the crystallisation. The straight line c corresponds to the shock-like rapid cooling-down. In doing so the polymer remains amorphous also below the temperature Tu, but is consolidated, however. During heating-up again, this latent energy DEn is can be utilised, i.e., a very rapid heating-up corresponding to the straight line c is possible.

The following process steps S1 – S4 are carried out:

S1 Shock-cooling (ts)

S2 Transfer into the LFT - press (tt)

S3 Initial heating-up again of the profile surface layer (11) during the LFT - pressing and

S4 subsequent cooling-down during the LFT - pressing (S4.1) and after the pressing (S4.2)

These process steps are further explained in conjunction with the Figs. 5b, 5c, 6 and 7. Figs. 5b and 5c illustrate the temperature control on the surface 11, resp., in lower a layer 13 below 11 and Figs. 6 and 7 illustrate the temperature dependence T(d) in the EF - profile 10, resp., in EF - profile and LFT `- mass 6 during pressing.

Fig. 5b illustrates a temperature control on the surface 11, resp., in a surface layer Ta(11) during the shock-cooling in the enthalpy diagram, this in conjunction with the Figs. 6 und 7. During the shock-cooling the surface 11 of the profile within the shock-cooling period ts is very rapidly lowered down to the temperature Ta1 (step S1). Subsequently, during the transfer time tt a temperature equalisation with a rapid rise again of the surface temperature to a temperature Ta2 takes place (step S2), which is situated clearly below the melting point Tm. During the subsequent pressing with the liquid LFT - mass 6, the profile surface 11 is initially heated-up again to a temperature Ta3 (step S3), which is situated above the melting point Tm, and in doing so is completely melted together with the LFT - mass. Subsequently in the step S4 a slow cooling-down takes place, initially still during the pressing (S4.1) and thereafter following the removal from the LFT - press (S4.2), wherein a further crystallisation takes place in the temperature range DTkr. A sufficiently good interface bonding and melting together EF-LFT, however, is capable of being achieved also with a stronger shock-cooling with a lower surface temperature Ta3* (after step S3), which is situated clearly above Tu, but slightly below Tm.

Fig. 5c illustrates the temperature control, resp., the temperature curve T(13) in a lower layer 13 below the surface 11of the EF - profiles (e.g., at a depth of 0.1 – 0.4 mm), in which a high crystallisation is produced by slow temperature control in the crystallisation temperature range DTkr for an enhanced form stability. During the shock-cooling (S1) a strong crystallisation takes place in the lower layer 13. During the temperature equalisation (step S2) in the transfer time tt and initially also during the pressing (S3), a

heating-up takes place, wherein the temperature, however, is kept below the melting temperature Tm, in order that the crystallisation remains preserved. These temperature changes in the layer lower 13 take place more slowly than on the surface (Fig. 5b). During the cooling-down (S4) a further crystallisation takes place. By means of a stronger or weaker formation of this crystallised zone in the layer lower 13, the required degree of dimensional stability for the transfer, positioning and pressing is able to be adjusted.

Fig. 6 illustrates the temperature gradient T1(d) with a surface temperature Ta1 in the EF - profile 10 following the shock-cooling at the point in time t = ts (step S1). Following the transfer into the LFT - press (step S2), rapidly a balanced temperature distribution T2(d) with a reached surface temperature Ta2 is achieved after a transfer time t = tt. The crystallisation temperature range DTkr (approx. 70 –125°C), in which the crystal growth takes place (kr in Fig. 5a), is also indicated.

Fig. 7 illustrates the temperature gradient in the EF - profile 10 and in the adjacent LFT - layer 6 (with a thickness df) during the pressing operation in the LFT - press. With the pressing, first the quantity of heat Q2 is transferred from the hot LFT - layer 6 with a temperature Tf to the EF - profile 10 (step S3). In doing so, a temperature distribution T3(d) is produced, wherein the temperature Ta3 on the profile surface 11 and at the interface 9 rapidly increases strongly and with this an impeccable melting together and bonding strength is achieved. Subsequently the temperature T4(d) in step S4 drops once again in correspondence with the LFT - tool temperature Twl. During the pressing together of EF - profiles 10 with the LFT - mass 6 and the subsequent cooling-down initially in the LFT - tool (S4.1) and then following the removal (S4.2), the temperature control can be selected in such a manner, that the crystalline proportion (at the required position) is increased by means of a correspondingly slower transition through the crystal growth temperature range DTkr.

In analogy to the differing thermal conditioning by zone in the profile tool 21, the LFT - tool 31 may also comprise differing thermal conditionings, resp., heat transfers by zone,

i.e., differing parameters: tool temperatures Twl and heat penetration coefficients ae in different zones of the LFT - tool.

Following the removal from the LFT - tool and after the cooling-down of the structural components, it is possible, that slight shape changes occur, this as a result of differing expansion coefficients of EF - profiles and LFT - mass and also of material contraction. These shape changes can be influenced, resp., compensated by means of a different temperature control during cooling-down in some places, by analogous thermal secondary treatment or also by a corresponding shaping of the tools, which compensates the shape change (pre-forming in the opposite direction).

In the case of partially crystalline polymers such as PP it is possible to select the temperature control in such a manner, that the crystallisation characteristics are exploited for the improvement of non-deformability and bonding strength. For example:

- In casing layer 12, resp., in the layer lower 13, it is possible to increase the strength of the casing zone in the crystallisation temperature range DTkr.
- On the profile surface 11 solely a minimum crystal growth can be achieved, if the surface temperature Ta in step S1 and step S2 is very rapidly brought through the crystal growth temperature range DTkr and the profile surface during the pressing is rapidly and as completely as possible melted open and bonded with the LFT - mass (by Q2).
- The shape stability is increased by a greater crystalline proportion in the casing layer, resp., in the lower layer 13
- and, depending on the required further shapability during the LFT - pressing, a smaller or greater crystalline proportion is produced in the casing layer, resp., in the lower layer 13.

A temperature gradient at the interface 9, resp., at the contact surface EF-LFT is capable of further increasing the strength of the joint EF-LFT by means of a directed crystal growth over the interface.

Figs. 8a, 8b, 8c illustrate possible shapings of the EF - profiles in correspondence with the differing functions and requirements at different points of a certain EF - profile, resp. structural component, this in particular for absorbing external loads. For this purpose, the EF - profiles may comprise a three-dimensional profile shaping, which is integrated into the structural component in a precisely defined position. They may comprise bends, twists or folds in longitudinal direction and they may comprise special shapings 22 for force transfers to the LFT - mass and for the direct absorption of external loads, resp., for the receiving of inserts 4 (mounting parts), at which external loads are introduced into the component. The shaping of the surrounding LFT - mass 6 is also selected to match the shaping of the EF - profiles 10. Shapings of force transfer points (of forces and moments) inside a component (e.g., of an EF - profile through the LFT - mass on to other EF - profiles) are able to be formed both as shapings 22 of the EF - profiles as well as shapings 32 of the LFT - mass.
In general as balanced as possible, continuous transitions are formed for the reduction of steps in strength and rigidity between the EF - profiles and the LFT - mass.
The three-dimensional shaping of the EF - profiles is implemented, e.g., by a pre-forming of the molten EF - tapes 5 in the horizontal plane by the tape gripper 18 and by pre-forming elements 19 during the transfer into the EF - profile forming station 20 (refer to Fig. 11). In doing so, the EF - tapes 5 may also be twisted. Subsequently the shaping also takes place in the third dimension (vertically) by the profile tool 21, so that to a great extent any required three-dimensionally shaped EF - profiles can be produced.

Figs. 8a, b illustrate the example of a complex structural component in the form of a 2/3 rear seat back 74 with a central seat belt connection 60 for the middle seat of a vehicle with several demanding load introductions for different load cases (crash loads). Fig. 8a in plan projection illustrates the arrangement of the EF - profiles in the component and Fig. 8b in a perspective view the LFT - mass 6 and drawn in it the integrated EF - profiles 10.1 to 10.4. This example illustrates the load-optimised shaping of the EF - profiles themselves as well as the load-optimised arrangement in a precisely defined position in the component to form a structure with a corresponding shaping of the LFT - mass 6 and with an optimum bonding strength between the EF - profiles carrying the

main loads (with directed continuous fibres) and the complementing LFT - mass (with undirected long fibres).

Here four main load carrying points L1 to L4 result from:

- the loads L1, L2 on the axle holders 59a, 59b, around which the rear seat back is able to be swivelled,
- the load L3 on the lock 58, for fixing the rear seat back in its normal position and
- the load L4 on the belt lock, resp., belt roller 60 for the central belt of the middle seat.

With this structural component the following load cases (with the further loads L5 to L9) are covered:

- Front - and rear collision
- Securing of any goods loaded
- Belt anchoring
- Head support anchoring.

For the receiving and transferring of all loads and forces the intersecting EF - profiles together with the joining force-transmitting shapings of the LFT - mass form a spatial, three-dimensional intersection structure 50. Here the EF - profiles respectively in pairs in the LFT – shapings form a moment-transmitting girder subject to bending:

- The EF - profiles 10.1 and 10.4 in a crimp 7 of the LFT – mass form a girder subject to bending between the loads L1 and L4
- and the EF - profiles 10.2 and 10.3 in the ribs 8 of the LFT - mass a girder subject to bending between the loads L2 and L3.

Through the three-dimensional intersection point 50, in this the load L4 on the belt roller and also in part other loads, which act on the girder subject to bending 10.1 / 10.4, is also supported on the other girder subject to bending 10.2/ 10.3 (and vice-versa).

The main forces, resp., loads L1 to L4 are received by means of force introduction points:

- through shapings 22 and 32 of the EF - profile ends and of the LFT - mass for receiving the external forces with or without inserts 4.
- In doing so, the inserts 4 prior to the pressing operation are able to be inserted into the LFT - tool and then pressed together with the EF - profiles and the LFT mass
- or else it is also possible to fit them into the component later on.

Here the EF - profile 10.1 comprises an arc-shaped widening 22.1 for receiving an insert 4 at the axle bearing 59a. The other axle holder receptacle 59b is formed by shapings 22.2 of the EF - profiles 10.2 and 10.3 and by adapted joining shapings 32.2 of the LFT - mass. These profile ends 22.2 are bent over and in this manner anchored in the LFT - mass for the purpose of increasing the tensile strength. The lock 58 is bolted on to a lock plate on the EF - profile 10.3 and supported by the EF - profile 10.2. The belt roller 60 is supported by shapings 22 of the EF - profiles 10.1 and 10.4 and by LFT - shapings 32.

The smaller loads L8, L9 of head supports 61 here are absorbed through LFT – shapings 32. For reinforcement, however, it would also be possible to integrate an additional EF - profile 10.5 deposited transversely (in some zones oriented flat or vertically).

In this example the three-dimensional profile shaping is evident in many variants.

The depositing sequence of the EF - profiles into the LFT - tool is:
first the EF - profile 10.1, thereupon the EF - profiles 10.2 and 10.3 and subsequently the EF - profile 10.4. Then the liquid LFT – mass 6 is introduced and the complete component pressed in a single step as a single piece and as a single shell. In order to obtain as short as possible transfer times tt, several or all EF - profiles (10.1 – 10.4) are able to be gripped with a multiple gripper 26 or robot, pre-positioned correctly relative to one another during the transfer and be inserted into the LFT - tool 31 together in a single step.

During the form pressing of the EF - profiles it is also possible to press several profiles in one profile tool 21 with a profile forming station, e.g., here the EF - profiles 10.2 and 10.3.

The profile shaping in the EF - profile forming station 20 in case of particularly complicated shapes may also be carried out by means of a multipart profile tool in a multi-stage shaping process. An example for this is illustrated in Fig. 8c with a three-part tool 21u, 21o and 21.3. In a two-stage shaping process, here first the tool parts 21o and 21u are closed and thereupon immediately on the side the tool part 21.3. In this manner it is possible to shape a 90° or 180° - arc - e.g., for zones, where forces are to be introduced.

Figs. 9a, 9b illustrate an example of an EF - profile 10, which over its length comprises differing cross-sectional shapes, this in adaptation to the forces to be transmitted and for the optimum bonding with the LFT - mass 6. The Figures in cross-sectional view illustrate an EF - profile 10a, 10b in a rib 8, e.g., corresponding to the profiles 10.2 or 10.3 of Fig. 8, at two different locations.

Fig. 9a illustrates a shaping 10a with a positioning shoulder 55 for fixing and holding the EF - profile in the required position - this especially during pressing, when the liquid LFT - mass is pressed into the rib. On top and underneath the EF - profile respectively comprises a thicker zone 56 as tensile - and compressive zones (in longitudinal fibre direction) for the transmission of moments. Located in between is a thinner thrust zone 57 with a correspondingly thicker adjacent LFT - layer 6 and with a large bonding surface area and a particularly strong interface joint.
With this, the shear resistance is increased by the adjacent LFT - layer 6 with isotropic fibre distribution (while the strength transverse to the fibre orientation in the EF - profiles 10 here is lower).

At another location according to Fig. 9b the profile cross-section 10b is changed corresponding to the force situation there: stretched, i.e., higher and narrower and without a positioning shoulder.
For the secure and accurate positioning and fixing of the EF - profiles, this also during the pressing with the LFT - mass, further positioning points 54 may be developed on the EF - profiles, which correspond to the shaping of the LFT - tool 31o (top) and 31u (bottom). Here the positioning point 54 serves for the accurate positioning below in the rib 8. Positioning points can also be arranged suitably distributed in the longitudinal direction of the EF - profiles.
In an analogous manner, profile shapes of this kind may also be positioned and fixed on crimped walls instead of in ribs 8.
Instead of the examples 8a, 9a, it is also possible to design the cross-sections of EF - profiles as "L"- or "Z"-shaped, depending on the application.

In addition to the shock-cooled EF - profiles, further shaped EF - profiles, which, however, have been treated separately and in a thermally inverse manner (i.e., solid inside, liquid outside), may be brought into the LFT - tool for the non-deformable transfer and pressed together with the shock-cooled EF - profiles in a single step. As an example, the EF - profile 10* according to Fig. 10 as a result of external heating-up is capable of comprising a molten external zone 89 and a still non-deformable cooler internal zone 88. For the handling and transfer, this EF - profile 10* may be gripped by means of cold grippers at (cooled by this) non-sticking contact points for a short period.

Figs. 11 and 12 illustrate examples of an EF - profile production line, resp., of an installation for the implementation of the method according to the invention. Fig. 11 depicts an example of an EF - profile production line with an EF - profile forming station 20, with a semi-finished products store 14, a heating station 15, with a protection gas atmosphere 27 (e.g., with N2, for critical materials and temperatures), with a conveyor belt or a chain conveyor 16 (e.g., a studded chain with a non-sticking coating and a brush cleaning system), a band gripper 18 with pre-forming elements 19, which are attached to the upper EF - profile tool 21o, an EF - profile forming station 20 with

shock-cooling, with a transfer portal 17 for the upper tool part 21o and with an EF - profile press 23. With a profile gripper 26 and a transfer robot, resp., a handling unit 42, the produced EF - profiles are transferred into the tool 31 of an LFT - press 30 and accurately positioned. From the semi-finished products store 14, the EF - tapes 5 with a suitable cut-to-size (also with varying length, width and thickness) are brought to the heating station 15 with the chain conveyor 16 and there, e.g., with IR - radiators are completely melted open and heated-up to a homogeneous required tape temperature Tp0. Subsequently the molten EF - tapes 5 are gripped with a band gripper 18 with pre-forming elements 19, which are attached to the upper tool part 21o, and during the transfer into the EF - profile forming station 20 are pre-formed (pre-formed in the horizontal plane, e.g., by means of positioning pins with bending or rotation of the molten tape), moved over the lower profile forming tool 21u with the transfer portal 17, deposited there in the required pre-formed position and immediately pressed in the precisely defined, adjustable shock-cooling period ts for the formation of the dimensionally stable casing layer 12. By means of the deformation in the profile tool, the required, defined three-dimensional shape of the EF - profile is obtained. Subsequently the EF - profiles 10 are immediately removed from the mould and with the profile gripper 26 transferred into the LFT - tool 31 of the LFT - press 30 by the robot 42 and accurately positioned. With the profile gripper 26 the EF - profiles 10 during the transfer are aligned to the required set-point position in the air, i.e., with respect to translation motion, rotation and inclination into the defined position for each individual EF - profile. With a profile gripper 26, resp., a robot, the profiles are able to be individually gripped and transferred or else also several profiles gripped at the same time and simultaneously respectively aligned to the correct position and then deposited together.

In the example of Fig. 8, e.g., first the profile 10.1, thereupon together the EF - profiles 10.2 and 10.3 are each respectively vertically positioned in a rib and then the EF - profile 10.4 is positioned in a crimp, wherein also these four profiles are capable of being simultaneously transferred and positioned with a multiple profile gripper 26.

In order to avoid, that the molten EF - tapes 5 remain stuck to the band gripper 18 and to the pre-forming elements 19, the tapes are able to be unstuck by means of a brief contact with cold gripper surfaces, which do not stick. A double-gripper of this type 18a, 18b comprises, e.g., two insulating small gripper contacts 18a and two stronger, cold, non-sticking gripper contacts 18b.

In an EF - profile forming station 20, with more than one profile tool 21.1, 21.2 it is also possible to simultaneously press several EF - profiles 10.

Fig. 12 illustrates a complete installation 40 with several EF - profile production lines with EF - profile forming stations 20.1, 20.2, 20.3 as well as with an LFT - processing facility 34, e.g., an extruder, and with an LFT - gripper 37 for transferring the molten LFT - mass 6 with the required temperature into the LFT - press 30, resp., into the LFT - tool 31. The installation comprises partial control systems for the individual sub-assembly groups: a control 25 of the EF - profile forming stations, a control 35 of the LFT - processing facility and an LFT - press control 36, which can be combined in the installation control system 45 including the control system for the transfer robot 42.

Fig. 13 illustrates the accurately defined positioning of several EF - profiles (10.1 – 10.4) in differing fitting positions and with any inclinations between flat and vertical in an LFT - tool. In this, the individual EF - profiles can be positioned on the lower tool 31u and/or also on the upper tool 31o and also be fixed with suitable fixing elements 38. With the LFT - mass 6 introduced in between therefore correspondingly also components with elaborate EF - profile reinforcement structures can be produced in a single step.

The LFT - mass 6 may also be introduced and pressed with other analogous compressive manufacturing processes instead of extruding. Thus it is also possible to utilise LFT - injection processes with horizontal pressing and a vertical LFT - tool. Applicable as particularly suitable is also an injection moulding process with back pressing in the source flow with a moving tool with submerged edges, where the tool during the

injection is first slowly opened and then pressed together. It is also possible, however, to implement a horizontal pressing with a vertical LFT - tool. Vertical injection with a horizontal LFT - tool is also possible.

Structural components according to the invention contain one or more shock-cooled EF - profiles 10, which comprise a precisely defined shaping and a precisely defined position in the LFT - mass 6 and therefore also in the structural component, so that external loads to be carried are capable of being optimally carried and supported. The production according to the invention in the shock-cooling process is able to be proven on finished structural components, e.g., by distinguishing shaping marks on the EF - profiles, which have been created by the handling elements during the production process, by slight roundings of edges on the EF - profiles and by harmoniously balanced transitions between EF - profiles and LFT - mass.

In the case of the preferred crystalline thermoplastic materials, on the EF - profiles 10 in preference in the zone of a lower layer 13 (of, e.g., 0.2 – 0.4 mm thickness) below the profile surface 11 an increased crystallisation 101 is generated (refer to Fig. 7).
On the contact surfaces 9 between EF - profiles 10 and LFT - mass 6, in preference a directed crystallisation 102 over the contact surface is generated. This also results in improved mechanical properties and in an improved stability over time of the structural components with shock-cooled EF - profiles.

Light, load-bearing structural components according to the invention with integrated, shock-cooled EF - profiles are capable of being employed in a broad range of applications, e.g., in vehicle construction for components such as chassis parts, doors, seating structures, tailgates, etc. The structural components in some applications can also be constructed with solely one integrated, suitable shaped EF - profile. Two examples of structural components with one single EF - profile are illustrated in the Figs. 14 und 15.

Fig. 14 illustrates a bumper beam support 92 with an EF - profile 10.1 integrated into the forming LFT – mass 6, which extends over the whole length. At two load receiving points L1, the bumper beam support 92 is connected with the vehicle chassis. The EF – profile 10.1 here is designed as "top-shaped", with slanting flanks 93 and integrated into the LFT - mass, as a result of which also an energy-absorbing crash-element is created. In another, reinforced variant, in complement it would also be possible to integrate a second EF - profile 10.2 on a crimp underneath the EF - profile 10.1.

Fig. 15 illustrates an assembly support (front end) 95 with an integrated EF - profile 10.1 bent on both sides with four load receiving points L1, L2, where the assembly support is attached to the chassis. Depending on requirements, the EF - profile 10.1 may also comprise a shaping or recess at these points L1, L2, which, integrated into the LFT - mass as a crash-element 93 is plastically deformable – in analogy to the example of Fig. 14.

Within the scope of this description, the following designations are used:

1	Structural component
1.2	Second part (two-shell)
4	Inserts, inlays
5	EF - tapes, EF – bands
6	LFT - mass, form mass
7	Crimp
8	Rib
9	Interface, contact surface EF-LFT
10	EF - profiles
11	Profile surface
12	Casing layer
13	Lower layer (layer below 11)
14	Semi-finished products store
15	Heating station
16	Chain conveyor
17	Transfer portal

18	Band gripper
19	Pre-forming elements
20	EF – profile forming station (shock cooling)
21	Profile tool
21o, 21u	Upper, lower
22	EF – profile shapings
23	Profile press
25	Control of EF – profile forming station
26	Profile gripper
27	Protection gas atmosphere
30	LFT - press
31	LFT - tool
31o, 31u	Upper, lower
32	LFT - shapings
34	LFT - processing, extruder
35	LFT - control of 34
36	LFT - press control
37	LFT - gripper
38	Fixing elements
40	Installation
42	Transfer robot, handling unit
45	Installation control system
50	Three-dimensional intersection point
54	Positioning points
55	Positioning shoulder
56	Thick tensile – and compressive force zones in 10
57	Thinner thrust zone
58	Lock
59a, b	Axle holders
60	Belt roller, belt connection, belt lock
61	Head supports

88	Internal zone
89	External zone
92	Bumper beam support
93	Crash element
95	Assembly support, front end
101	Enhanced crystallisation
102	Directed crystallisation
LFT	Long fibre thermoplastic
EF	Continuous fibre
ae	Heat penetration coefficient
d	Direction vertical to the profile surface 11
dp	Thickness of the profile
df	Thickness of the LFT - layer
Q1	Heat transfer at 21
Q2	Heat transfer from 6
t	Times, periods
ts	Shock-cooling period
tt	Transfer time
T	Temperatures
Ta	Surface temperature
Ti	Temperature inside, internal temperature
Twp	T of EF – profile tool 21
Twl	T of LFT - tool 31
Tf	T of LFT - mass
Tm	Melting temperature
Tp0	T of EF - tape 5
Tp	Input temperature of EF - profile 10
Tu	Lower solidification temperature
T1, T2	Profile temperature curves
DTkr	Crystallisation temperature range
kr	Crystal growth

DEn	Hysteresis range (crystallisation heat, latent enthalpy)
L	Loads
En	Enthalpy
S1, S2, S3, S4	Process steps